❖ The first report of the Red Pine Pocket Decline syndrome From the Allegheny National Forest

An evaluation of Red Pine Mortality in Compartment 819 Stand 28
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Observations were made of mortality in compt 819, std 28 of the ANF. The observations did not fit the already published model for red pine pocket decline in Wisconsin. A modification of the existing model is proposed along with methods to test the model. While this report is the first of Red Pine Pocket Decline on the Allegheny National Forest, this syndrome is not new to the ANF. In this report there is no intention to imply that red pine stands on the Allegheny National Forest are about to go into decline. However, there is an intention to point out that highly stressed trees, in unthinned stands, will undergo a "biological thinning" and that biologically thinned stands will have undesirable holes in their canopies.

Stand Description

The SILVAH stand exam data indicated that the stand is now 59 years old, which would indicate an establishment year of 1937. However, a ring count from a disc cut at ground level gave only 52 rings. Allowing an additional ring for the 98 growing season and assuming the seedlings were 2yrs old at planting this would predict a planting date of 1945. This date agrees with local knowledge, which states that this stand was planted by German prisoners of WWII. The stand has an area of 23 acres and in 1996 had a basal area of 137 sq ft/ac. Of which, 67 was in red pine, 47 in Norway spruce and 23 in other species.

Apparent Growth Rate and Stand History

An initial walk through of the stand indicated it had been established with alternating (north-south oriented) rows of Norway spruce and red pine. Cut stumps of many red pine indicated that the stand had been thinned, yet there was no evidence of thinning slash. Apparently the thinning was distant enough for the slash to have decayed beyond recognition. Many stems displayed a distinct crook about 30-40 feet above ground, likely the result of wind or ice damage about 20 years ago.

The reason for the persistence of the red pine thinning stumps lies in the tendency of red pine plantations to become root grafted. In this way the remaining stems make use of the root systems of the thinned trees. The stump root systems become an extension of the grafted trees, as the stand develops a communal root system. In exchange for water and nutrients (taken up by the stump's roots) the living trees supply the stumps with the photosynthate necessary to keep their cambium alive. From a forest pathology point of view, the cut surface of the stump can be viewed as a wound on the root system of the living trees to which it is grafted. It was hoped that the basal disc used to compute tree age would reflect a growth release caused by the thinning. There was no evidence that the cut tree had ever responded to a thinning.

Although the stand may have started out as an equal mixture of spruce and pine, today it is dominated by red pine. It is possible that during thinning the slower growing Norway spruce was selected against. Today, the Norway spruce accounts for about one third of both the stocking and the basal area. The average pine is about 16 inches and the average spruce about 10 inches.

A basal disc was used to estimate the relative growth rate of a single representative of the stand. This particular tree had an acceleration of growth at age 10. At that age, the red pines would have begun to attain a dominant canopy position as they overtook their slower growing Norway spruce neighbors. From 11 to 17 years the tree made good growth, although there was a gradual decline in growth rate after about year 20. In the last 7 years this tree had made almost no radial growth. On the radius examined, the last seven years growth was only 4 mm (about 1/6 th inch), while the previous seven years achieved six times this growth rate and at its peak (yr. 11-17) the growth rate was 16 times greater than over the last 7 years. Clearly, if this stand is to be conserved much longer it needs thinning. In fact, it may well have needed thinning 7years ago.

The assumption that this growth decline over the last 7 years is due to only competition requires further investigation. This particular tree was standing on the edge of a mortality pocket and might have been in decline from agents other than competition. The tree was carrying two years of needles (some three-year-old needles were found on the leader). While it had some dead needles, it had a relatively full crown and was a dominant tree. Yet leader increment indicated it had been under stress in recent years. In the last growing season, the tree had made only 3 inches of height growth. In the previous 4 years the height growth had been 9, 11, 14, and 16 inches, respectively. (If increment cores are taken from trees well away from the mortality pockets it would be possible to separate the growth loss impact of competition from that of a disease pocket.)

A Description of Mortality Pockets in Compartment 819 Stand 28.

There are two major mortality pockets within this stand. Both pockets are broadly oval with the longest axis in the direction of the planting rows (north-south). The smaller pocket measures 150 by 120 ft and the larger measures 300 x 200 ft. The forest floor of the smaller pocket appears as "an almost circular green throw rug on a large brown carpet of dead pine needles". The forest floor within the small pocket is dominated by a cover

of the dark green colored *Lycopodium* (groundpine). Away from the pockets the forest floor is completely covered with conifer needles. This is almost certainly a reflection of the increased level of light now reaching the forest floor within the pockets. When the deciduous shrubs present come into leaf the impression of a green oasis on a brown background might not be as spectacular as it was before spring.

Fallen trees can be found at the center of both pockets. These trees are extensively decayed and appear to have been windthrown. They may have been down for 10-12 years and may have been dead for several years before the current mortality episode began. Yet, it does appear that the mortality centers are focused on some initial disturbance. Standing at the edge of the mortality pocket are some dead trees with all their needles still attached, while other marginal trees have a few dead needles scattered through out their crowns. It is not known if trees away from the pocket have a similar percentage of dead needles within their crowns. The outermost dead trees have crowns with fine branches and many dead needles still attached. Inward from these trees, the dead trees have no needles and few fine branches. Inward from this second cohort of dead trees is a third on which there are no fine branches. Ultimately, one would expect the pocket center to be dominated by dead spars with few if any branches. Figure 1 is provided as a schematic representation of a mortality pocket for clarity the spruce trees are not shown. As few of the Norway spruce have died, mortality pockets will not become dominated by dead spars but be dominated by released Norway spruce trees.

The mortality is confined to red pine. While the pocket mortality has been bad for the pine it has released the spruce. Thus the Norway spruce dominates the pockets. The spruce trees within the pockets appear to be healthy. While this observation alone, would tend to reduce the probability of this being a root rot caused by the omnivorous *Armillaria,* it would not eliminate the possibility of this being of the pine type of Anossum root rot.

It is worth noting, that there are no wind thrown recently killed trees. In this respect these pockets are not like those associated with Annosum root rot (caused by *Heterobasidion annosum*). Although this fungus is best known from the West, *H. annosum* has been reported from Pennsylvania (Gilbertson and Ryvarden, 1986). Despite having a shallow rocky soil, there was no evidence of recent wind throw within these pockets.

Armillaria root rot (caused by several species of *Armillaria*) is not present in these pockets. That is not to say the fungus *Armillaria* is not present. To cause a disease (i.e. kill trees) the fungus has to act as a pathogen. Pathogenic attack of conifers is characterized by basal resinosus of the attacked trees (Tainer & Baker, 1996). The root collar area of all dead trees within the smaller pocket was examined for the presence of pathogenic *Armillaria* attack. In all, 41 trees were examined (two were spruce). In no case was an example of pathogenic *Armillaria* attack observed. Yet *Armillaria* rhizomorphs were very common; in one case old *Armillaria* sporophores were found, emerging from a split in the bark and attached to the rhizomorhs beneath the bark. While, *Armillaria* is very common it, is not acting as a pathogen; it is acting as a saprophyte causing a sapwood rot of dead pines.

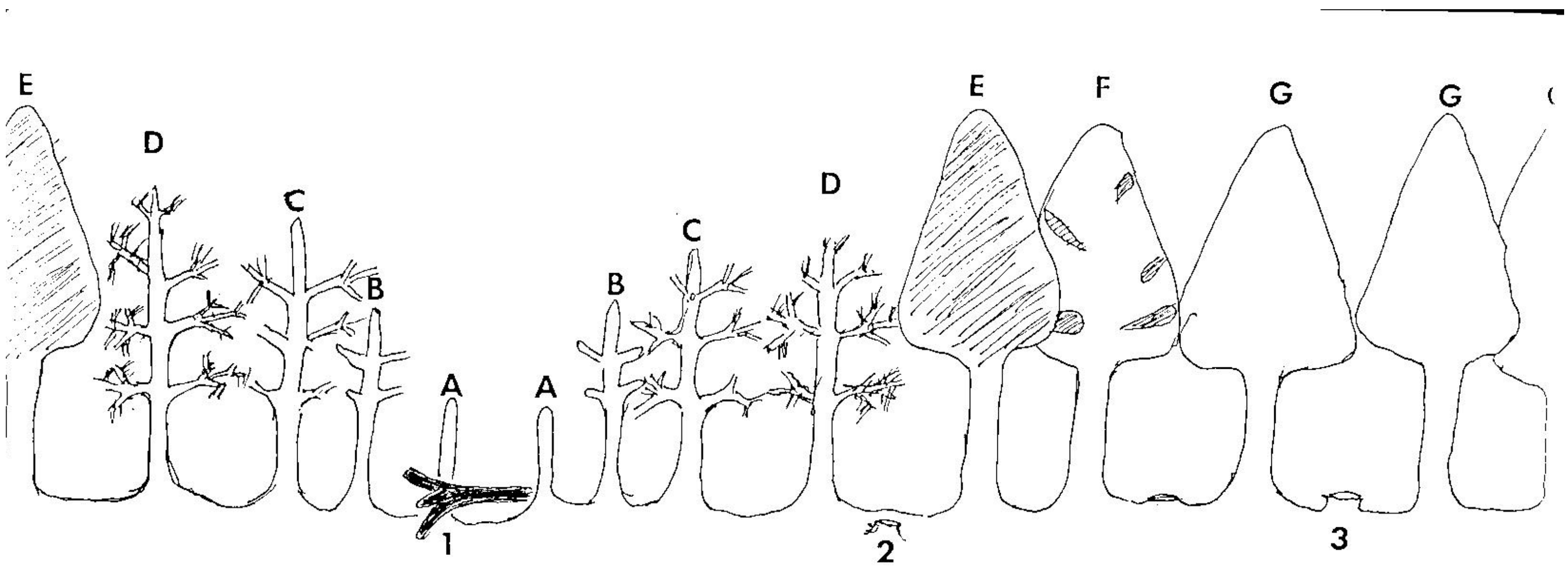


Figure 1

A Representation of a Red Pine Mortality Pocket In Compartment 19 Stand 28 of the ANF

KEY

A. Dead spar with no branches.
B. Dead spar with a few branch stubs.
C. Dead tree with major branches but few fine branches and no needles
D. Dead tree with fine branches and some needles still attached.
E. Dead tree with dead needles still attached.
F. Living/Declining tree with some flagged branches
G. Living /Healthy Trees out side the pocket.

1. The focal point dead tree with sprung roots (this tree has been dead longer than any others)
2. Dead root grafted thinning stump within the pocket.
3. Living root grafted thinning stump outside the mortality pocket.

Although a search was made for the sporophores of *Heterobasidion annosum,* none were found. Sporophores of the pouch fungus *Cryptoporus volvatus*, although not common, were found. This is only the second time the author has seen this fungus in the East. It is very common, as a secondary decay fungus on bark beetle killed conifers, in the drier areas of the West. While examining trees a record was kept of the pitch tubes which usually indicate attack by one of the *Dendroctonus* beetles. Pitch tubes were observed so infrequently that no further investigation of the role of these beetles was conducted. Small, superficial cavities filled with shredded wood were observed on the roots of one dead tree. These might have been the remains of chip cocoons of a species of weevil. Again, as this observation was not repeated, weevils were not investigated further.

Discussion of "Red Pine Pocket Decline Syndrome".

Klepzig and Carlson (1988) published a leaflet on "How to Identify Red Pine Pocket Decline and Mortality". They described a syndrome which is almost identical to what has been observed in Compartment 819 Stand 28 of the Allegheny National Forest (ANF). They implicate fungi of the genera *Ceratocystis* and *Leptographium.* Which they describe as pathogens and go on to state, **"The significance of these fungi in this syndrome is not known."** Only two of their observations were not repeated on the ANF. There is no evidence of a distress crop of cones on any dead or dying trees, and repeated isolation onto selective media has failed to yield any species of *Leptographium*.

Klepzig, Raffa and Smalley (1991) reported on a three-year study of this syndrome in which they focused on the root grafted nature of red pine stands. They postulated a radically expanding wave of belowground root mortality, which precedes above ground symptoms (reduced radial growth and crown thinning) that immediately precede tree death. Their scenario has the following steps:

1. Moderately pathogenic *Leptographium* species are introduced into the thinning stump or root system of a stressed pine. By using a vector insect the fungus gains access to the communal pine root system.
2. Spreading through root grafts, these fungi kill the roots of adjacent trees.
3. The root mortality spreads in a radial manner.
4. Trees within the area of greatest root mortality become so stressed that weevils and bark beetles successfully attack them. The *coup de grace* is administered by the Pine Engraver bark beetle (*Ips pini*).
5. The now dead trees become suitable breeding material for even more insect vectors of the *Leptographium* pathogen.

The weakness of the Klepzig et al (1991) scenario lies in that the *Leptographium* species implicated in this syndrome, *L. terebrantis* and *L. procerum* are only, at best, week pathogens of highly stressed trees. In their paper they made the following statement;

> **"Neither of these two fungi have been reported to be capable of causing mortality when inoculated into mature trees."**

The author suspects that to get *L. terebrantis* infection of red pine seedlings in a greenhouse the seedlings would have to be drought stressed. When working with a similar fungus (*L. truncata)* the author found that greenhouse seedlings of *Pinus radiata* had to be drought stressed to the point of wilt before the fungus could successfully infect them. On reviewing the genus *Leptographium,* it can be concluded, the only species capable of killing trees is the Western, *L. wagnerii*

Isolations were repeated on three occasions from both fresh material and from discs incubated in damp newspaper. As *Leptographium* species were not recovered from living trees, dead trees or thinning stumps both living and dead; it can be assumed that *Leptographium* is uncommon in the pockets of compartment 819 stand 28, on the ANF. In a recent publication, Harrington and Wingate (1997), (both researchers who have published extensively on the subject of *Leptographium*) made the most emphatic statement, to date, on the subject of the reputed causal agent of red pine decline. They state:

> "Red Pine decline in the Lake States has been associated with root–feeding weevils, bark beetles and at least one *Leptographium* species (*L. terebrantis*), but **some as yet unidentified predisposing factor seems to be involved in this complex syndrome of tree mortality."**

Red Pine Pocket Decline Syndrome, an Alternative Model.

In their explanation Klepzig *et al* (1991) made the point that mortality could still take place even if one of the components of the syndrome were absent. Essentially, their explanation involved the actions of several components, which act independently. Each component would have the effect of nudging the ecosystem slightly in one direction. As all of the components were nudging the system in the same direction, it mattered little that none of the components was, on it's own, capable of causing tree mortality. Thus, unlike most of the well-documented decline models, this one lacks a primary incitant.

While the published model for red pine decline in Wisconsin (Klepzig *et al,* 1991) might fit the situation in that state, it does not fit the observations of mortality pockets in Pennsylvania. In the mortality pockets on the ANF, there was little evidence for either bark beetles or weevil attacks at ground level. An inability to isolate *Leptographium* species makes it difficult to accept a model that relies on their presence. The decline syndrome, on the ANF, must follow a different decline spiral. Several observations (listed below) of the ANF pockets lead to another explanation for the decline syndrome.

1. Bob McBride (of the ANF staff) observed that trees with flagged branches could be seen on the edges of the pockets. He thought this was the first sign that a tree was going to decline (*pres comm*). Is this the first symptom of a tree that has entered a decline spiral?

2. A tree, which had appeared to have been dead for two years, was felled. At stump height there was no blue staining; this tree appeared sound and salvageable as pulpwood. At 30 ft there was little staining, but a cross sectional disc cut at 40 ft had

extensive blue staining. It was as if the staining in this tree was spreading down the bole from where, prior to death, the first live branches would have been attached.

3. Limbing the second and third trees, both living, revealed a significant amount of staining in the whorl of dead branches at the internode immediately below the green crown. In the first whorl of branches of the green crown some staining was also detected. These were branches which had several dead needles attached. Initially, it was thought this needle loss was natural winter death of second year needles (these trees had no third year needles). At 50 ft, in one tree, an actively expanding conk of *Cryptoporus volvatus* was found. This is a fungus usually associated with secondary sapwood decay of bark beetle killed trees (Harrington, 1980). At 55 ft the bark of the tree was easily removed. Of the 23 inches of inside-bark circumference, only 2 inches had an attached bark. Further, the cambium under the2 inches of attached bark had recently died. Although there were plenty of green needles on this crown it would have turned red as soon as the weather warmed up. (It was snowing on the day that this tree was felled.)

4. On the second living tree felled the situation was similar. At 41 ft, only 9 of 33 inches of under-bark circumference had attached bark. When the bark was peeled off there was a clear line of demarcation between the blue stained wood associated with dead cambium and the white wood associated with the attached and living cambium. On further examination, it was obvious a significant potion of cambium in the lower crown of both trees was dead, and had been for some time. The galleries and pupation chambers of bark beetles plus the larvae of flatheaded borers were found in the surface of the sapwood beneath the dead bark. Judging by the size of both the galleries and the larvae, it would be safe to assume the borers had overwintered in this tree.

Based upon the absence of bark beetles plus weevils (at ground level) and the apparent absence of *Leptographium* the following scenario for red pine decline on the Allegheny National Forest is postulated:

A. The syndrome only develops in stands with severe between tree competition. It will only develop after competition has begun to slow individual tree growth. Thus the syndrome will not develop in stand which have been thinned in a timely manner.

B. The syndrome is initiated after some major disturbance creates a hole in the canopy of an already stressed stand. Blowdown or ice-storms are two possible disturbances which would create openings and leave stressed trees at their margins.

C. Some sun loving insect is attracted to the upper boles of stressed trees on the edge of newly created pockets. If the initial insect attack is successful, the syndrome will progress further; if not, we have nothing more than a single dead tree in the forest. In the vast majority of cases the syndrome will not progress. In the last 50 years only two pockets have developed in this stand, and in the majority of pine stands on the ANF there are no mortality pockets.

D. If the initial insect attack is successful, that insect, or a secondary one introduces stain fungi. Once established, the stain fungi colonize the sapwood and slowly reduce the water supply to branches, which begin to flag and eventually die. As the stain fungi spread and the bole dries out, and it becomes attacked by a cascading succession of secondary organisms (both fungi and insects). The disease spiral initiated by the primary attack may continue over a period of several years. The tree declines, with final death appearing to be sudden. In the initial phases of the decline spiral, the only detectable reaction at ground level might be a reduction in radial growth. A sudden reddening of the crown, immediately before tree death would follow several years of reduced height growth.

E. After the dead tree has lost its needles, the bole of the adjacent tree is now exposed to the sun, and should the environment place that tree under stress it may become attractive to the initial syndrome inciting insect. If the environmental conditions necessary for a successful attack of a subsequent tree are not present, the decline syndrome stops; and we have a small hole in the plantation canopy. Subsequently the edge trees will respond to the increased sidelight by developing larger crowns.

The "Decline Spiral" of Manion and Lachance (1992) has been adapted (figure 2) to represent the model, described in points A through E (above). Perhaps, the most important aspect of the proposed model is that it has three places where either the tree or the stand can break out of the spiral. Over the past 50 years on the ANF it has been far more common for a stand or a tree to break out of the spiral than it has been for an individual tree to complete the spiral. On the ANF good red pine health has been the norm.

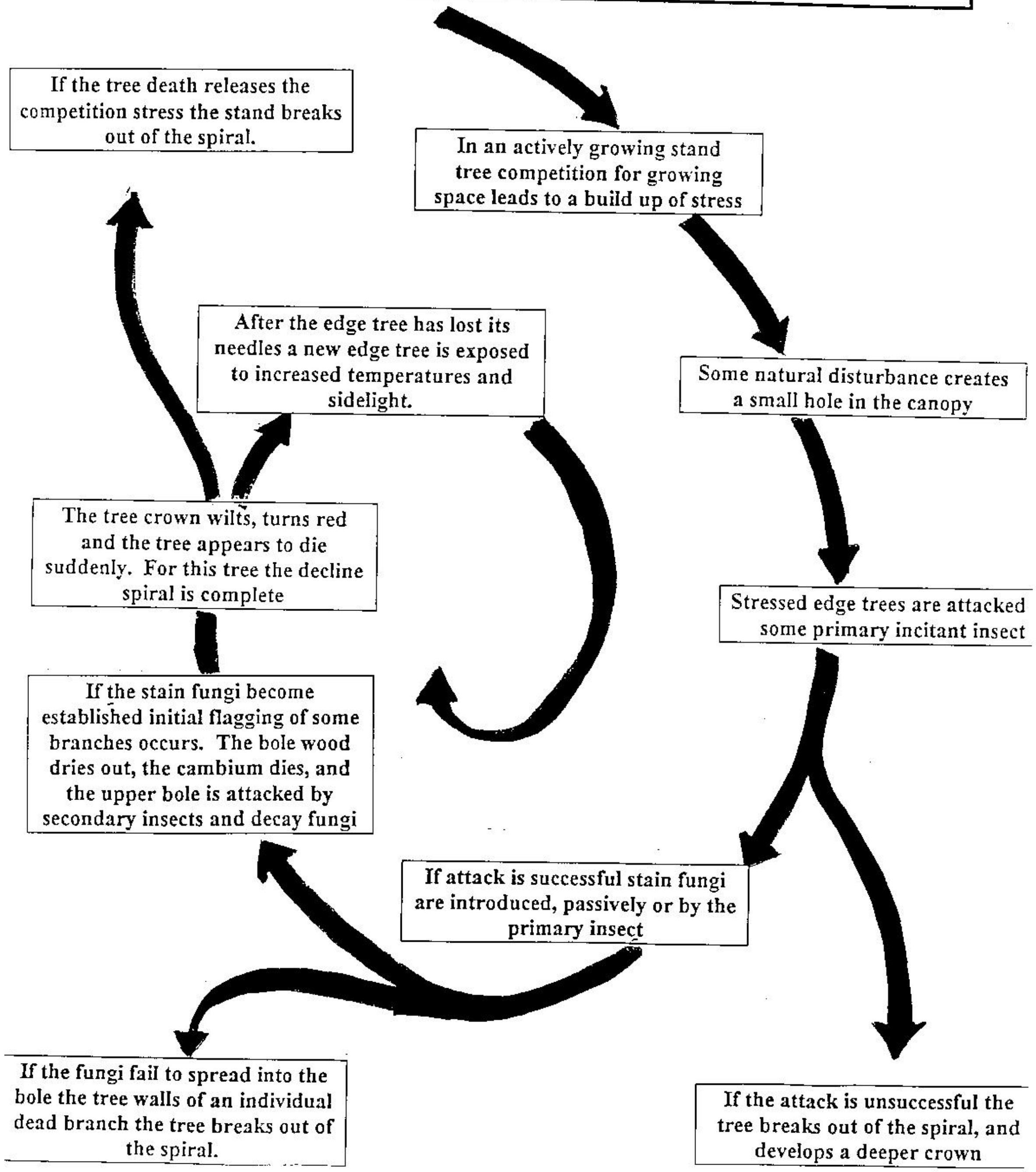
Trees at the edge of a stand are different from those at the edge of a newly created pocket, for they have been exposed to sidelight all of their life. Pine trees along the boundary road of Compartment 819 have crowns that extend almost all of the way to the ground. In contrast, trees within the stand have their first live branches at 30-40ft. Thus, if a hole is suddenly created in the canopy 30-40 ft of bole will receive levels of side light and temperature they are not initially adapted to. Should there not be an insect attack in the first year or two the trees adjacent to the hole-will adapt to their new micro-environment; develop larger crowns and become as resistant to attack as roadside trees.

While it is postulated that insects introduce stain fungi to upper bole, this is not the only way these fungi could enter the tree. The *Nectria* fungi that cause Beech Bark Disease of American Beech trees do not need an insect vector to reach the minute feeding wounds left by the scale insect. The *Nectria* spores are carried in wind currents (Houston and O'Brien, 1983). Similarly, the spores of the pouch fungus (*Cryptoporus volvatus*) reach the exit hole of bark beetles on wind currents (Harrington, 1980).

Figure 2

Proposed Model for Red Pine Pocket Decline on the Allegheny National Forest,

based on the model of Manion and Lachance.



At several steps in this model, the expansion of the pocket can stop. This does not mean the primary inciting insects die out. They simply fly to another part of the forest. If the pine stands are thinned to prevent the build up of the stresses associated with severe competition there should be no significant losses to pocket decline. There will, however, still be the occasional tree deaths as the insects maintain their populations (at low levels). This is what professor Manion describes as **"a healthy level of mortality"** (*personal communication*).

A strategy for treating Red Pine Pocket Mortality

The point of this report is to provide Forest Managers with a best case scenario for management of this stand. While this may be the first report of the "Red Pine Pocket Decline" syndrome on the Allegheny National Forest, this syndrome is not new to the ANF. Several years ago the author examined a dead tree, on the edge of a red pine mortality pocket in a stand in the village of Highland. At that time, evidence of a root collar weevil, and not much else was found. Steve Wingate, the silviculturist of the Ridgway Ranger District (ANF), prescribed that the mortality pocket be clearfelled. Further, he prescribed that all trees with a fading crown be harvested. Since that time, only one more tree on the edge of the pocket has died, (the one with weevil damage). To gain an insight as to what this prescription leads to, some time was spent investigating the Highland stand. A second mortality pocket has developed since the harvest of the first pocket. At this time, it includes only two trees. There is no evidence of additional mortality around the edge of the harvested pocket. Today, that pocket has regenerated back to red pine, with a few white pine and hemlock seedlings.

As the *Wingate solution* has worked well once, there is no reason not to try it again. As the model proposed in figure 2 requires the presence of a population of a primary insects the success of the Wingate strategy in the Highland Corner stand might have been dependant on timing. Thus, it is recommended that the treatment of Compt 8 19 Stand 28 be scheduled for the same month as was the Highland stand treatment. No pathological reason can be found to indicate that existing pockets in the stand should not be harvested as the stand is thinned. Norway spruce established within the pockets should be retained. All pine trees on the edge of mortality pockets should be removed. Further, the pocket edge should be pushed back two live trees to remove both, any building populations of insects and any already edge-stressed trees. The two openings created in the stand should be replanted with a conifer either, white or red pine. However, as the site was once dominated by hemlock, this is another species to consider. Planting a hardwood or a mixture of hardwoods and pines are alternatives that spread the pathological risk.

Shrub regeneration within the stand has an obvious browse line, and the numbers of pellet groups indicate that significant numbers of deer congregate in this stand over the winter. The investment in planting should be protected with deer-proof fencing.

Proposals for future work.

A. To ascertain the proportion of radial growth decline due to either the pocket mortality or suppression I plan to compare increment cores taken from trees at the edge of, and distant from pockets.
B. I plan to compare the last 10 years growth of trees that had died 1, 2, 3 and more years ago. This will indicate how many years before death there is a detectable growth loss at breast height.
C. If I can obtain a set of climbing ladders I will inspect edge trees for insect damage on the open side. Observations made of trees distant from the pockets will be used as a control.
D. I would like to look at some similar red pine plantations on other parts of the forest. In a preliminary walk through three other red pine stands, I found one additional pocket.
E. As I plan to fly the forest with John Omer during the sketch mapping exercise, I will pay particular attention to the pine resource of the ANF.

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